Engineered Particulates for Co-Firing of Diverse Feedstocks

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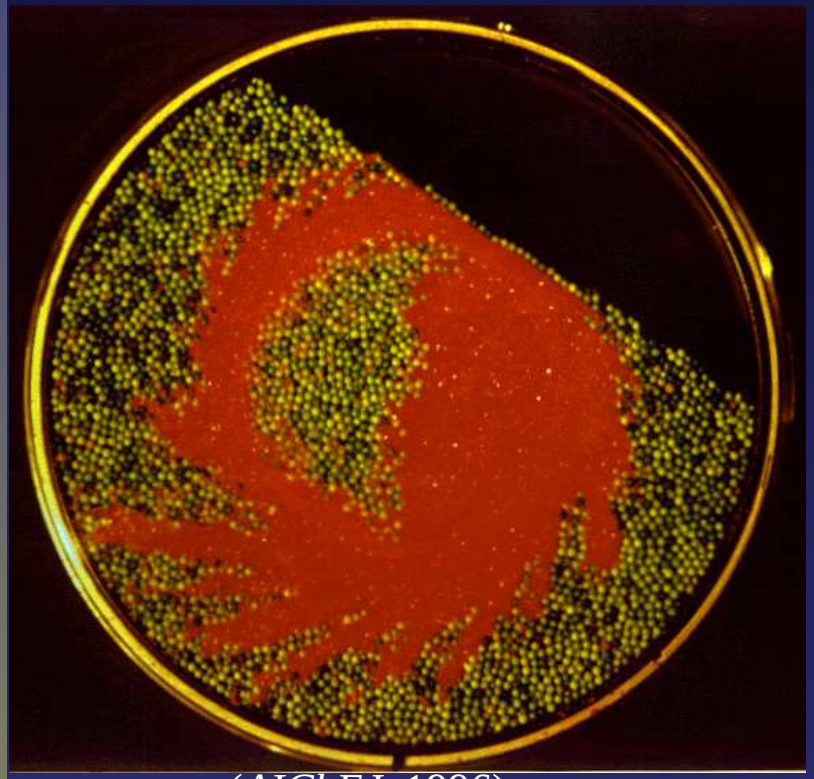
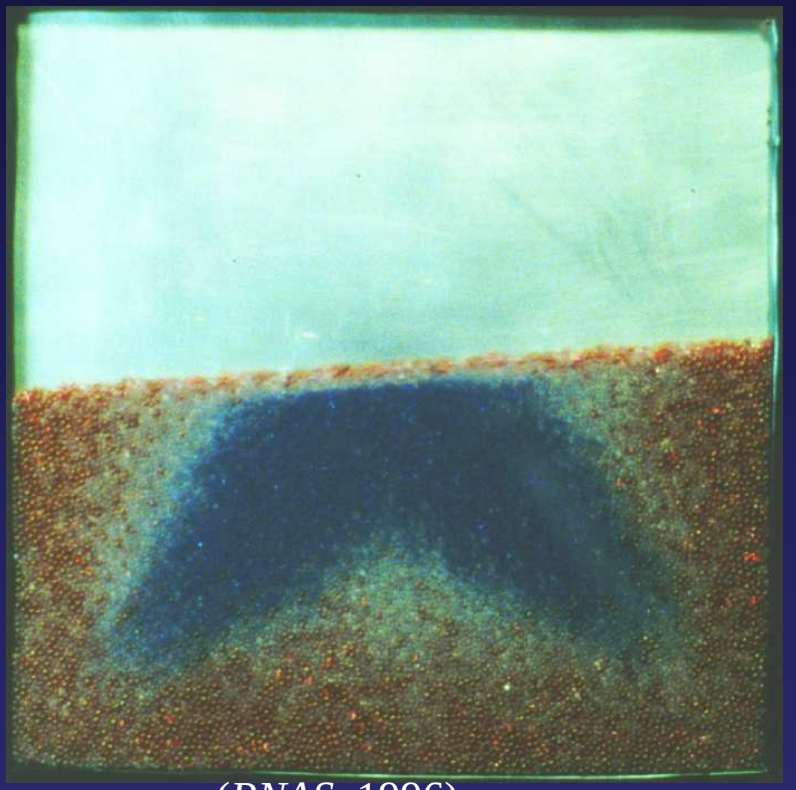
NETL-UCR/HBCU/OMI Workshop

Motivation



(*AIChEJ*, 1996)

Segregation &

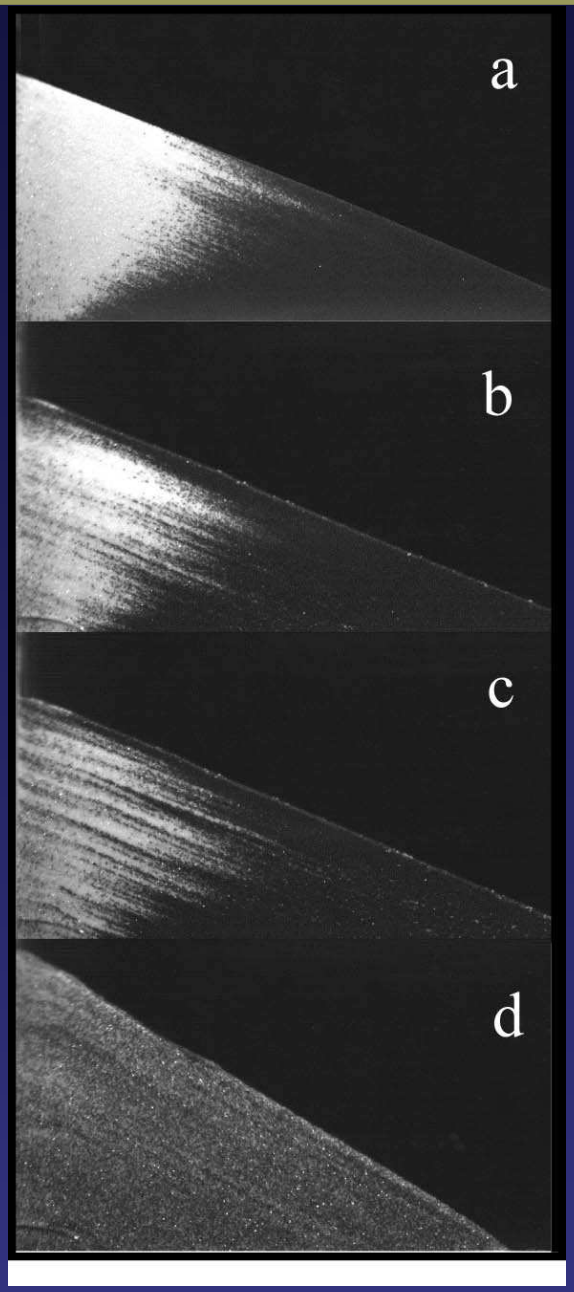


(*PNAS*, 1996)

Pattern Formation

- Differences in mechanical properties
- Inconsistent feed (possibly burn quality)

Motivation (cont.)



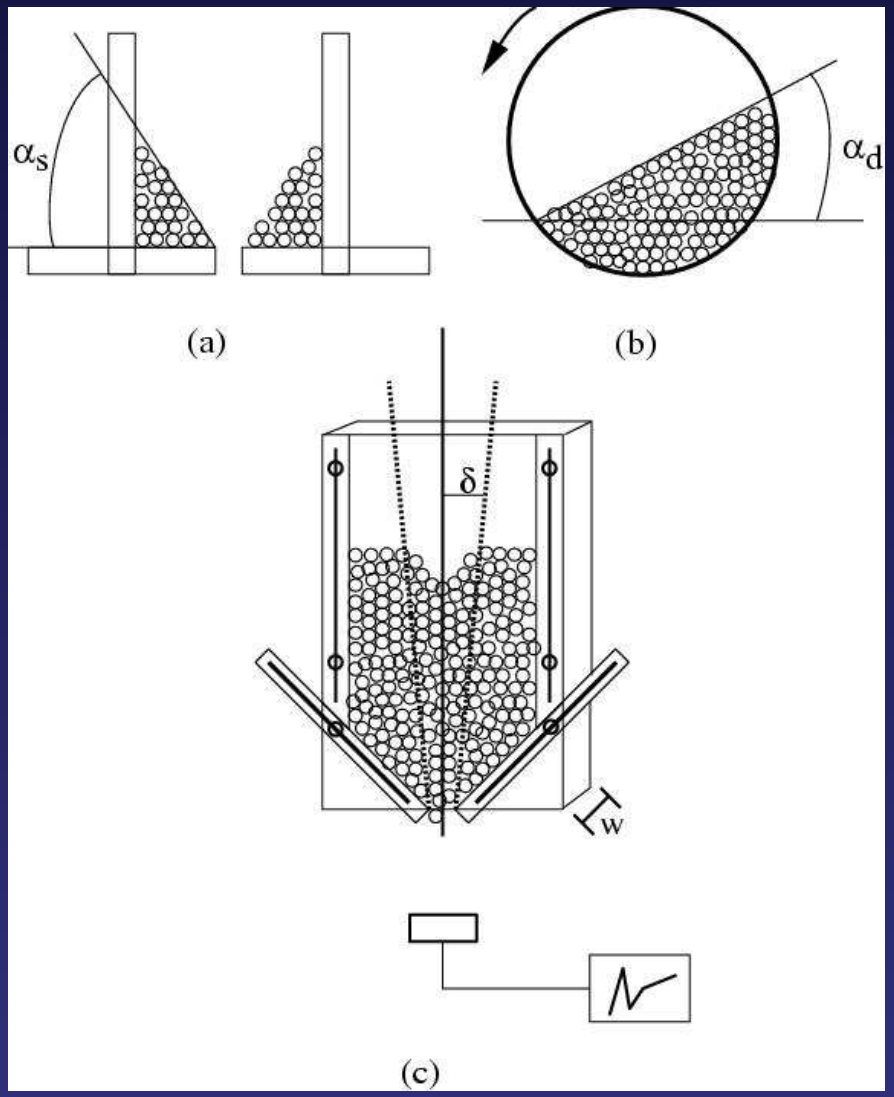
Cohesion sometimes segregation!

- Known long – recent quantitative studies
- can this be controlled?

Outline

- Cohesive Characterization Tools
  - Static systems
  - Sheared systems
  - Gas-solid systems
- Mixing/Segregation – Aggregate Formation
  - Psuedo-Static systems
  - Sheared systems
  - Gas-solid systems

Cohesive Characterization Exps.

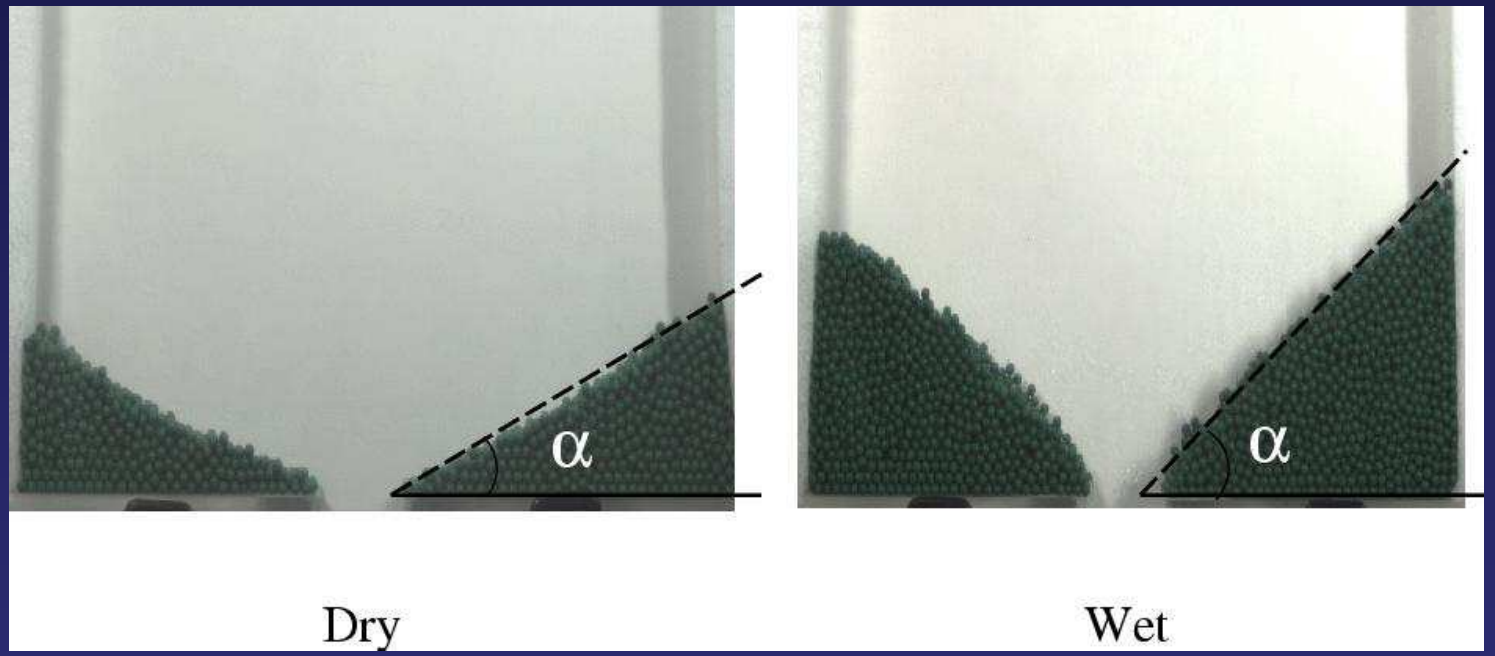


- "Perfectly" static (a)
- Prototypical granular flows (b) and (c)

Static Systems

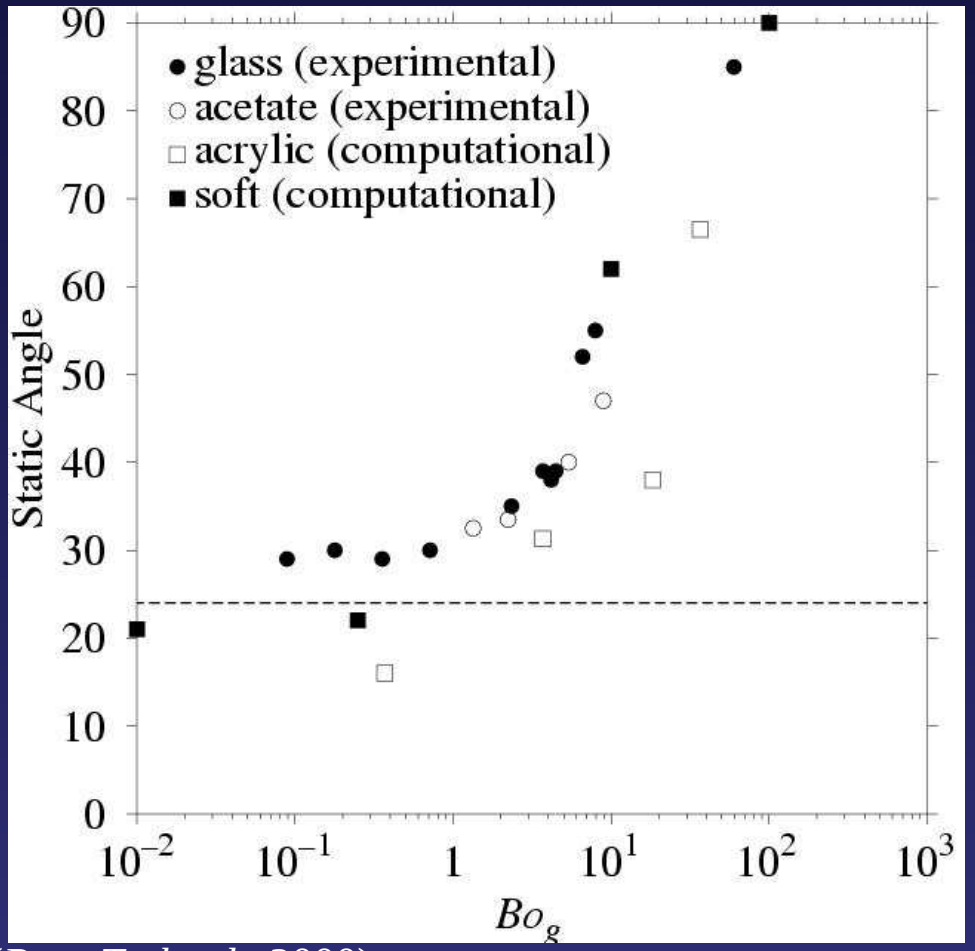
Relevant Forces

- Particle self-weight (W)
- Capillary Force (F_c)



$$Bo_g = \frac{F_c}{W} = \frac{3\gamma}{2R^2\rho g}$$

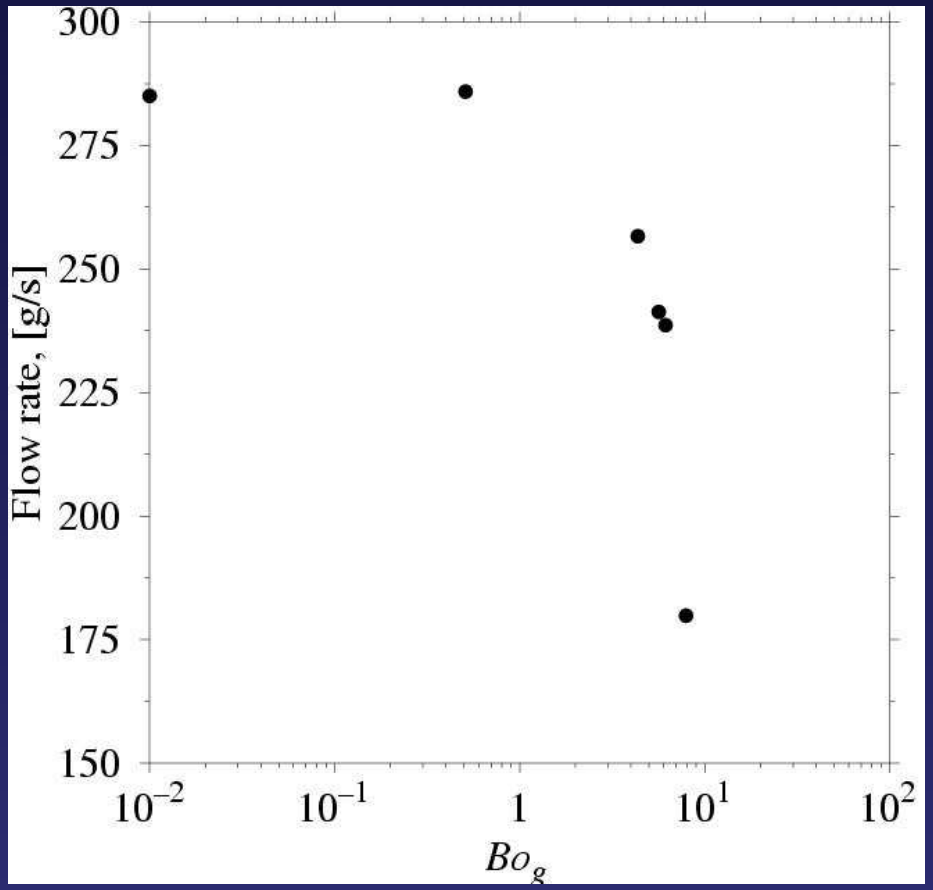
Angle of Repose - Static Heap

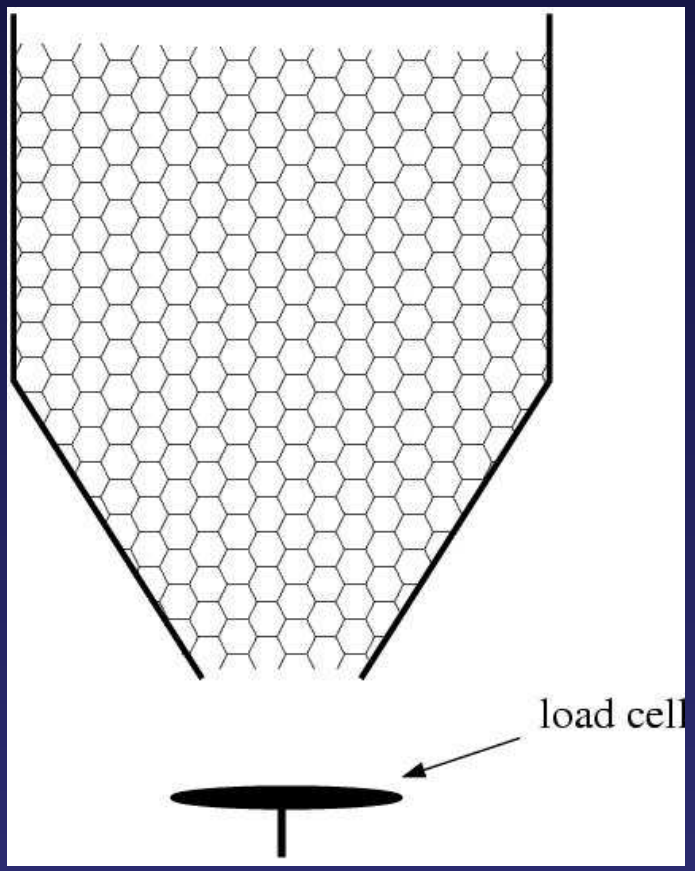


(*Pow. Technol.*, 2000)

- Sharp transition near $Bo_g = 1$
- Vastly different materials all follow same trend

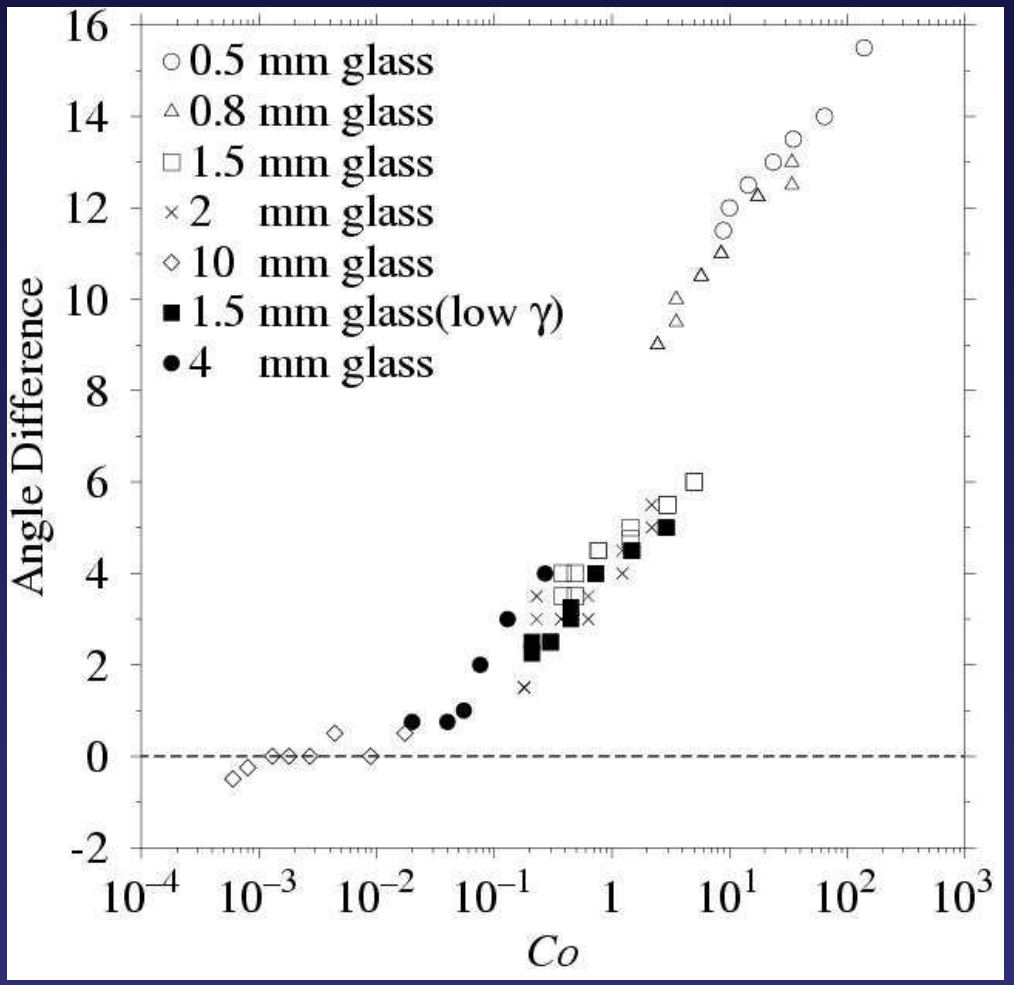
Hopper Discharge





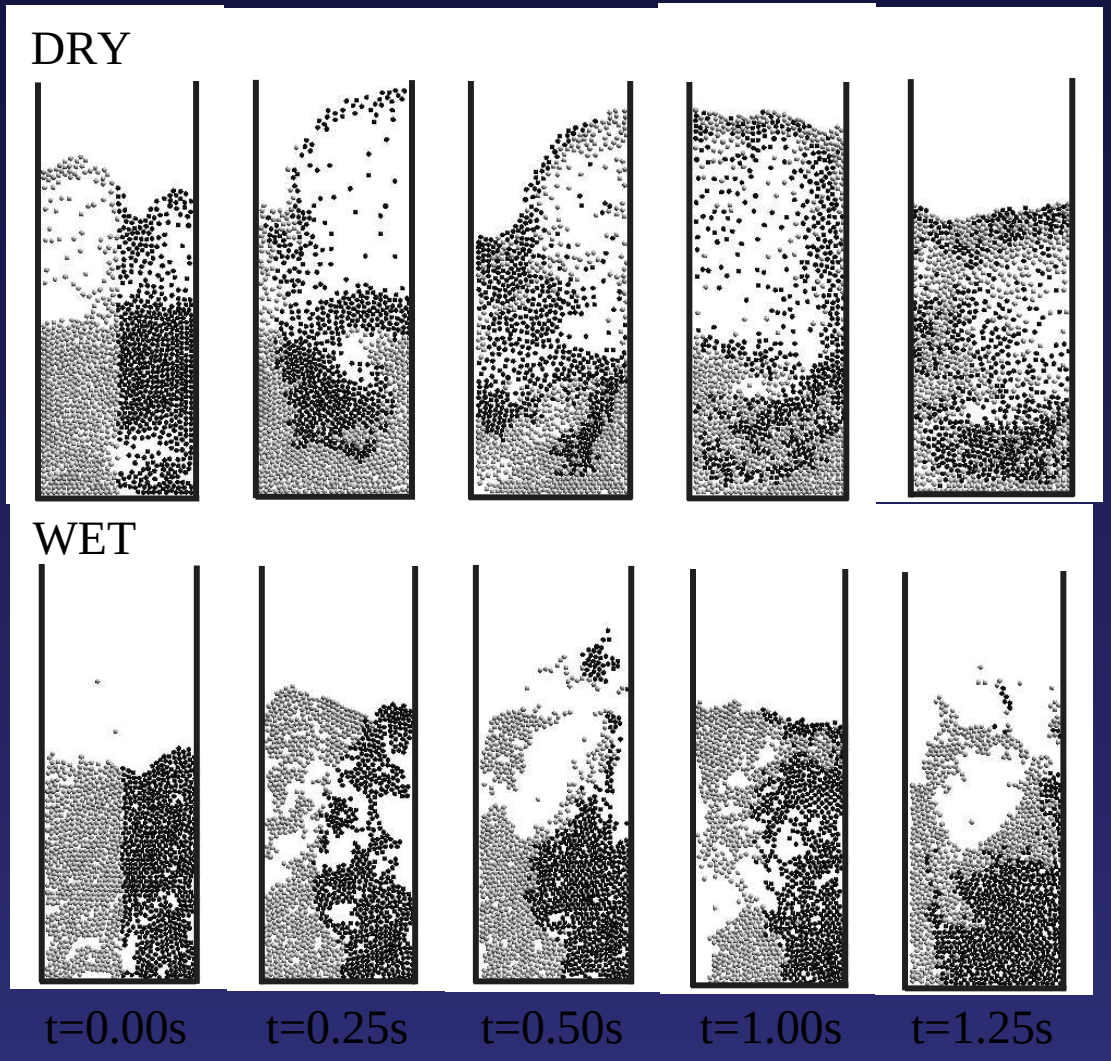
- Sharp transition above $Bo_g = 1$
- Essentially no flow thereafter (arching occurs)

Collision Number



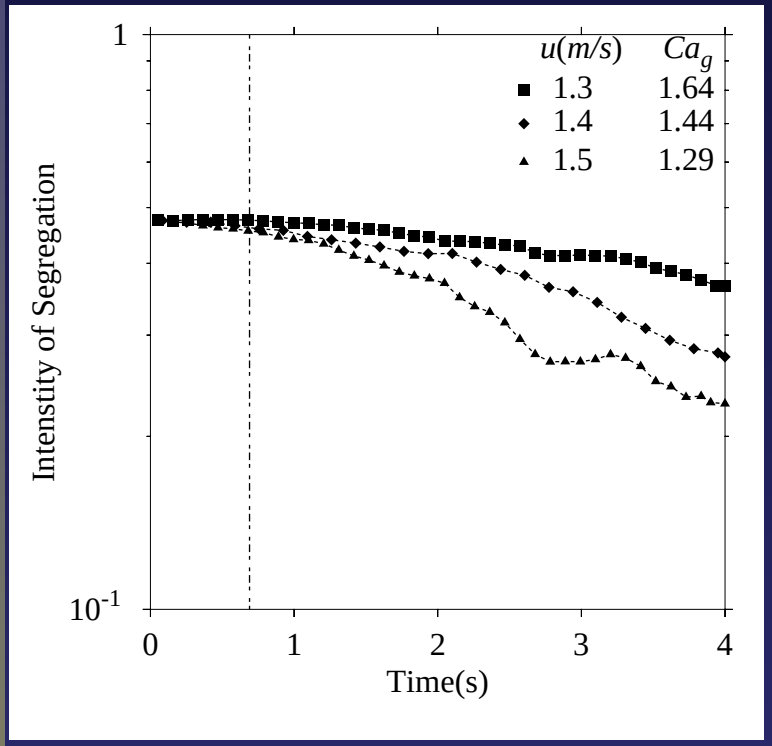
- Sharp transition near $Co = 1$

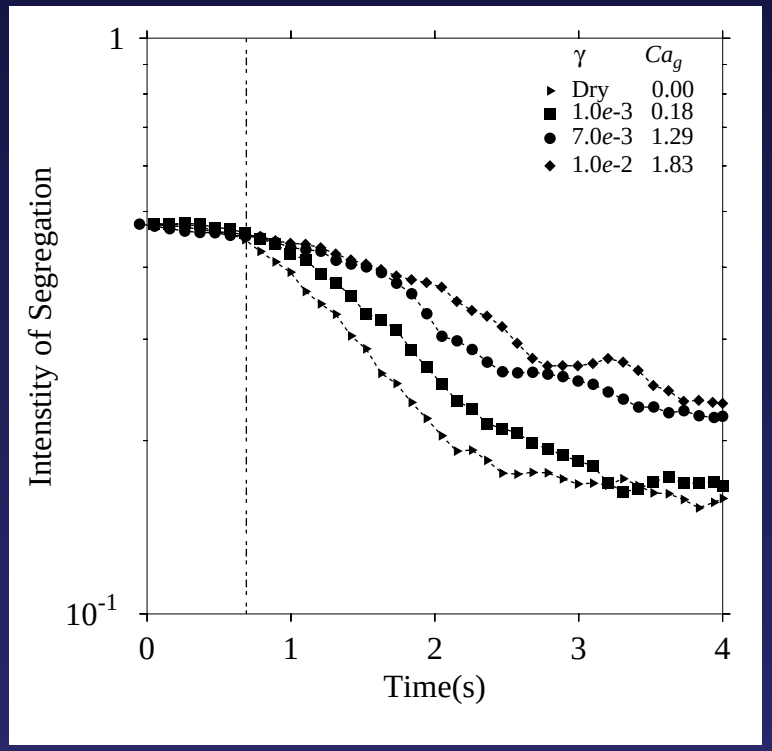
Gas-solid Flows



- Mixing rate changes with cohesion
- Minimum fluidization velocity *also* changes

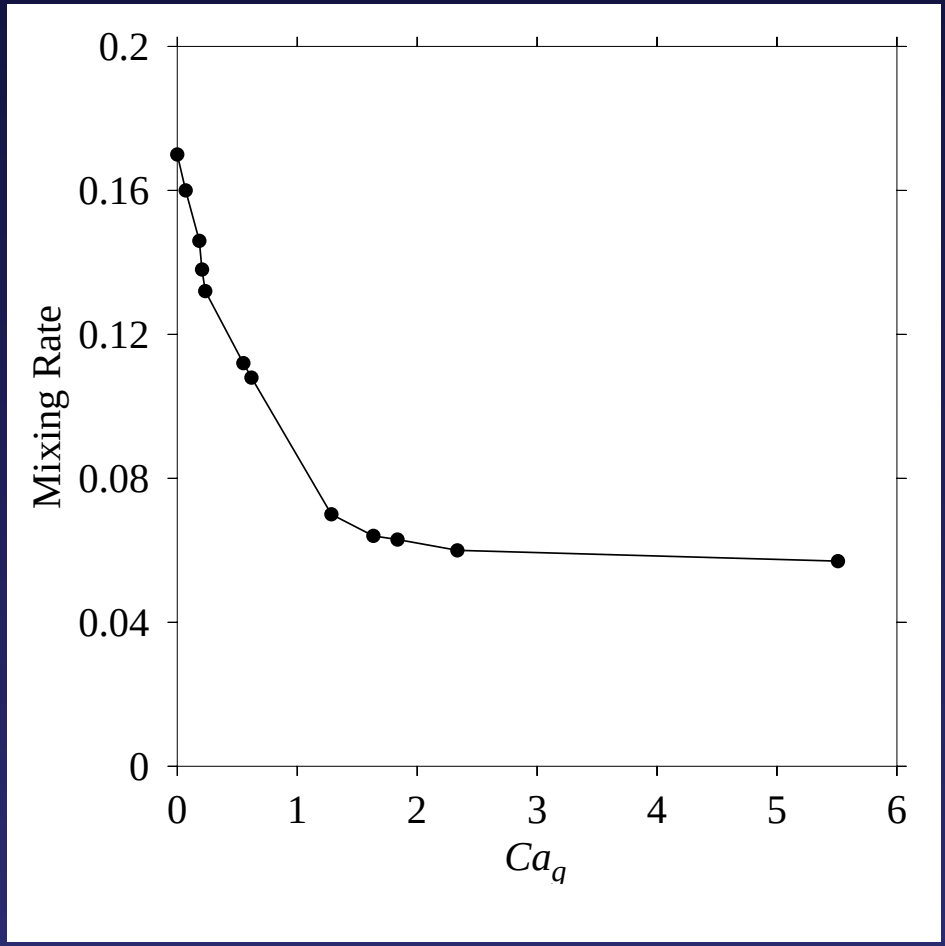
Gas-solid Mixing





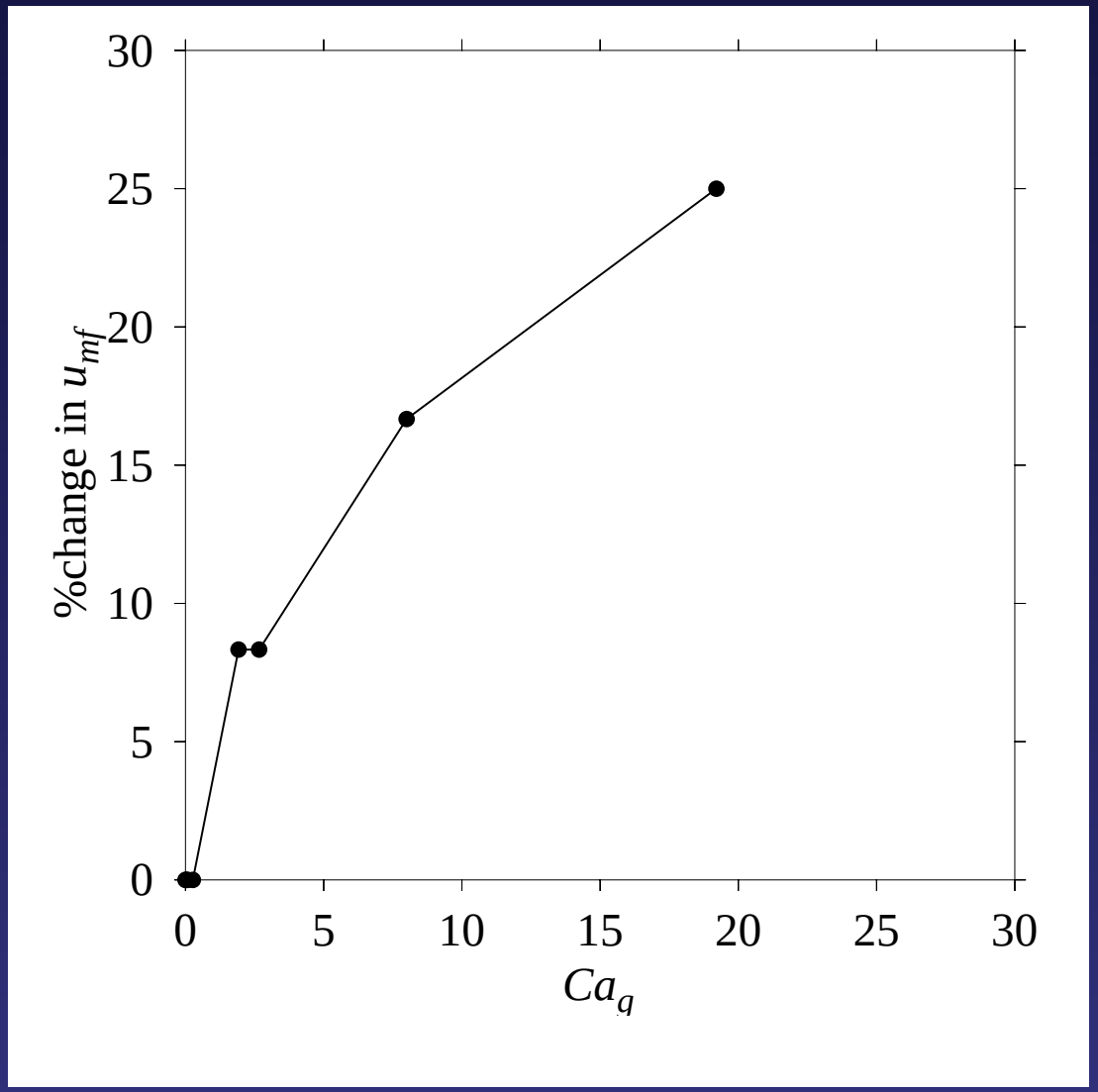
- Increase in fluidization velocity $\approx$ decrease in γ

The Capillary Number

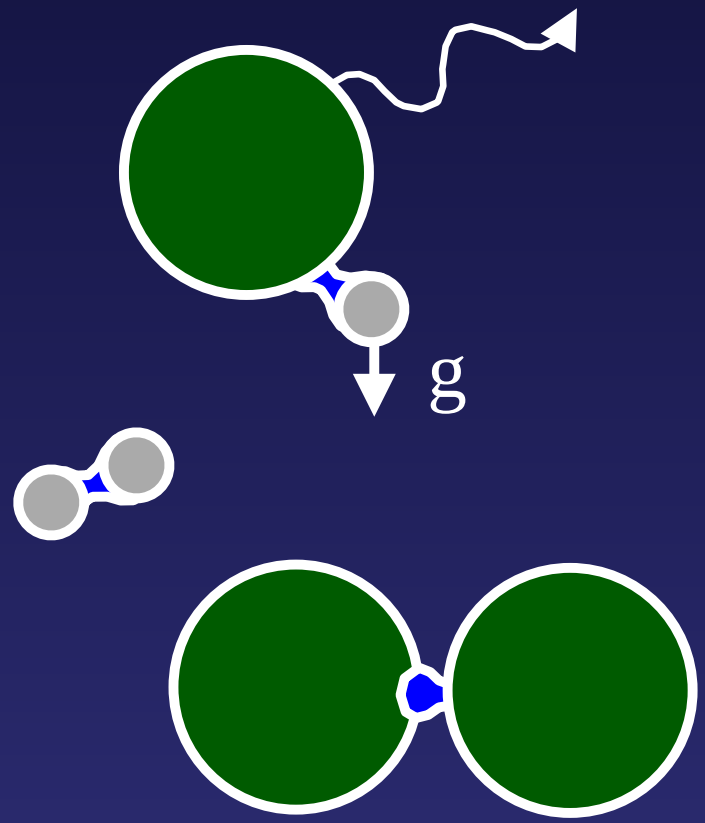


- $Ca_g = \frac{12\epsilon^3\gamma}{(1-\epsilon)(u-v_p)}\left[\frac{1}{300(1-\epsilon)\mu_g+7\rho_g(u-v_p)R}\right]$
- Two curves collapse with Ca_g

The Capillary Number (cont.)

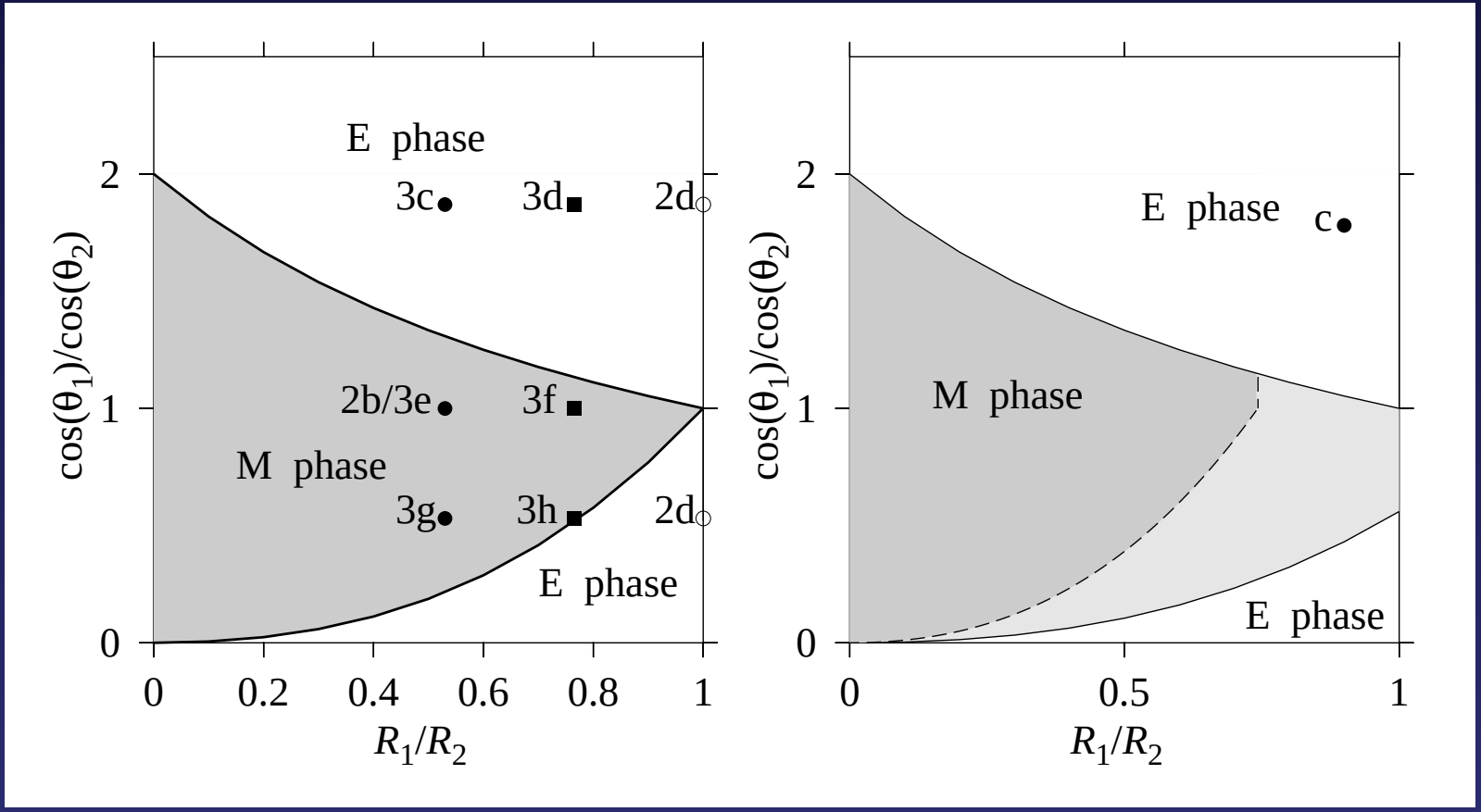


Micro-mixing Model – Static Systems



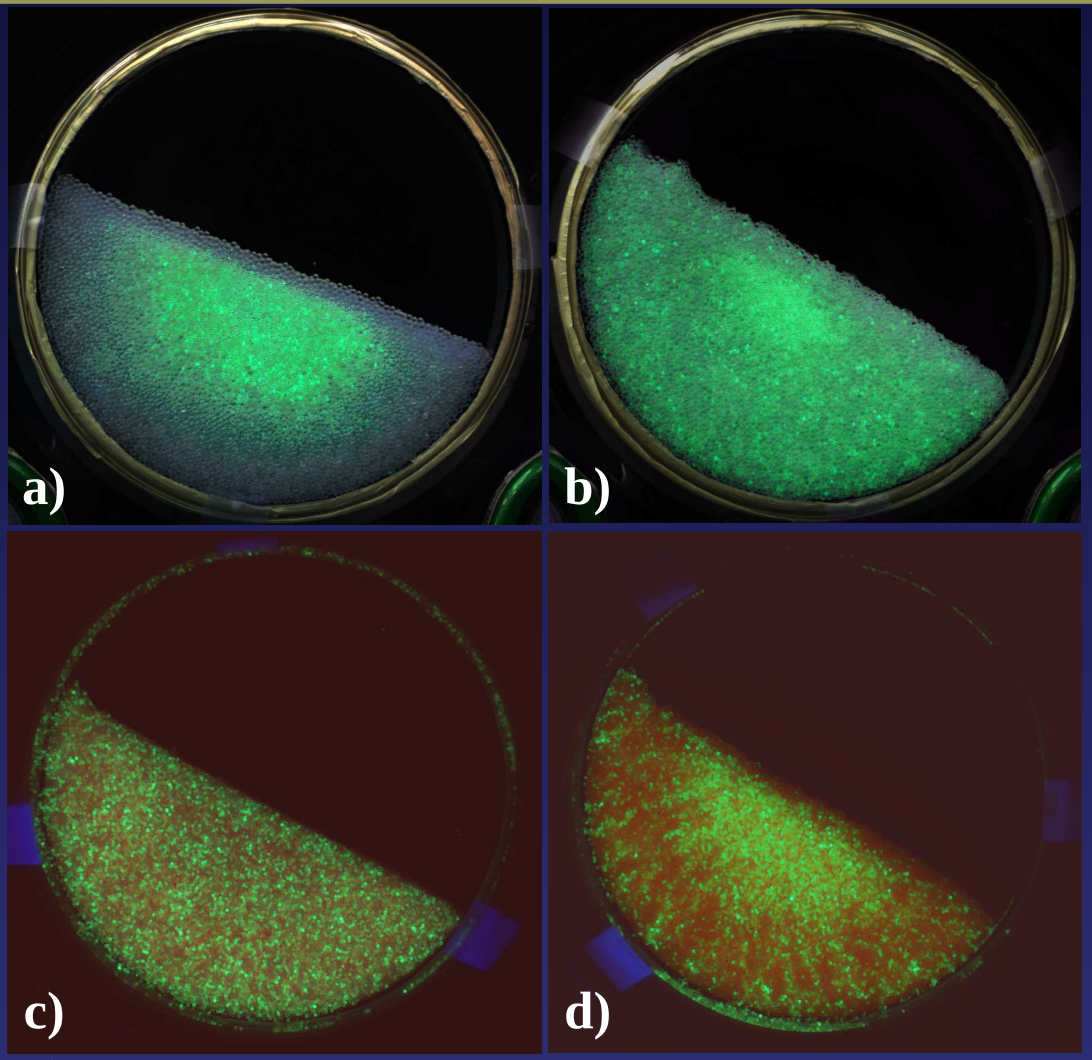
$$Bo_g = \frac{2\pi R_{eff}\gamma}{\frac{4}{3}\pi\left(\rho R^3\right)_{min} g}$$

A Phase Diagram



- Predict both “mixed” and segregated phases

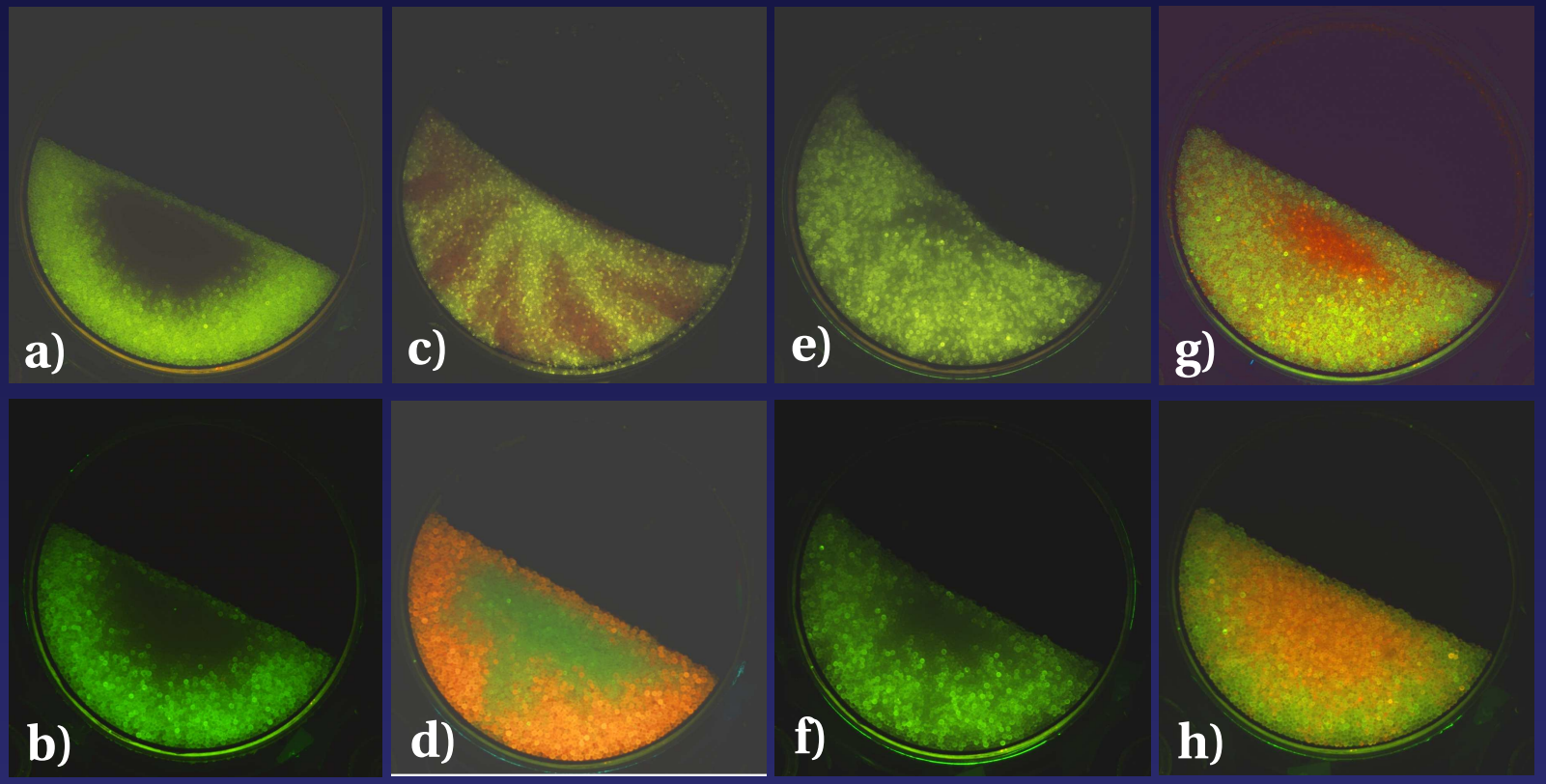
Manipulating the Phase Diagram



(*PRL*, 2003)

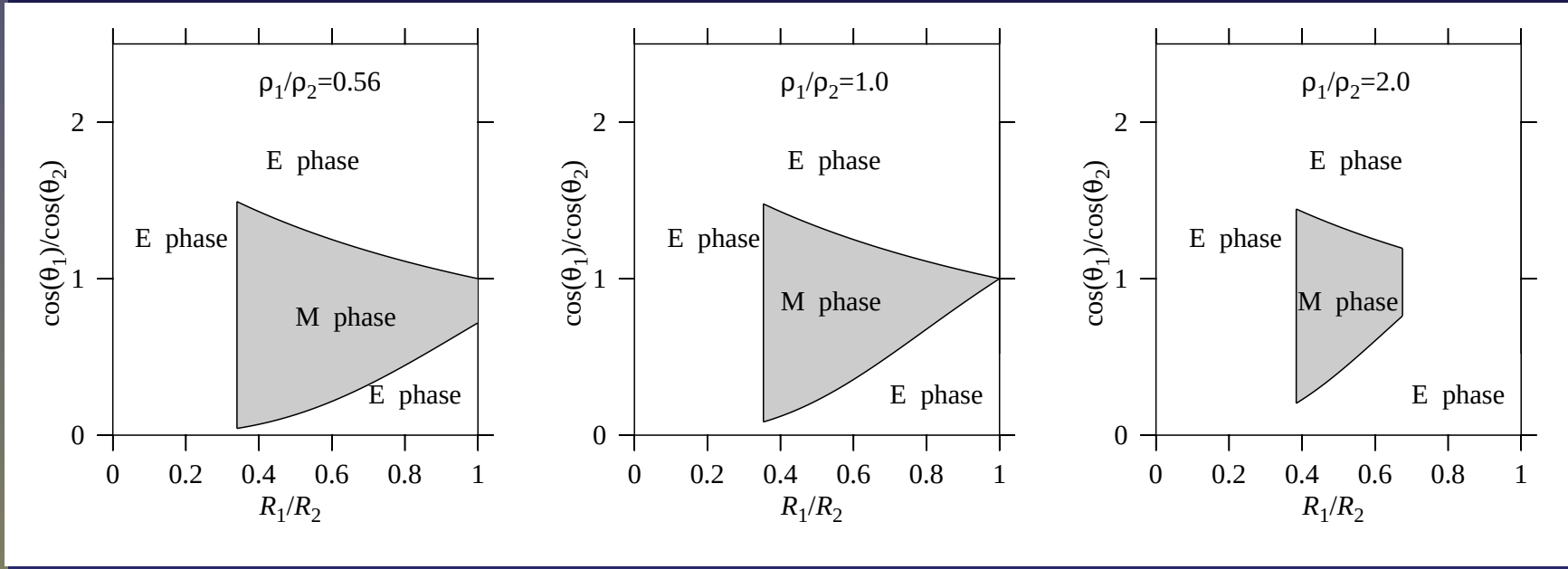
- Control mixing/segregation via surface properties!

Controlling Mixing/Segregation

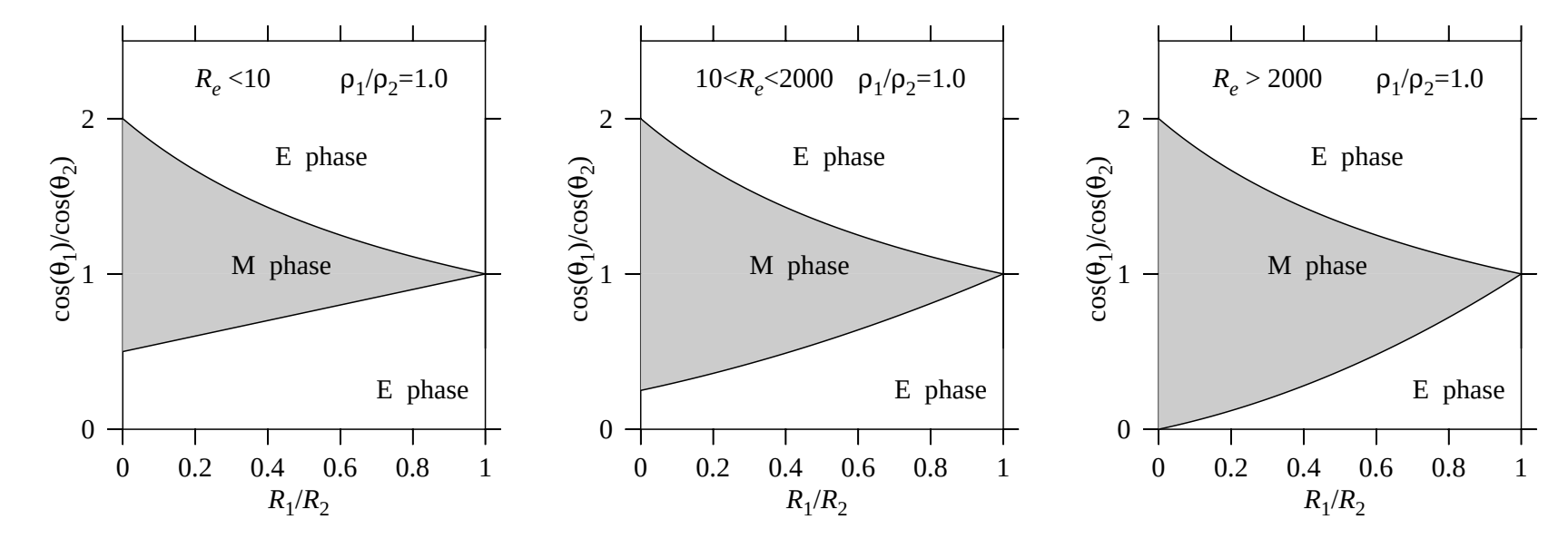


- Materials that would mix can be made to segregate and vice versa

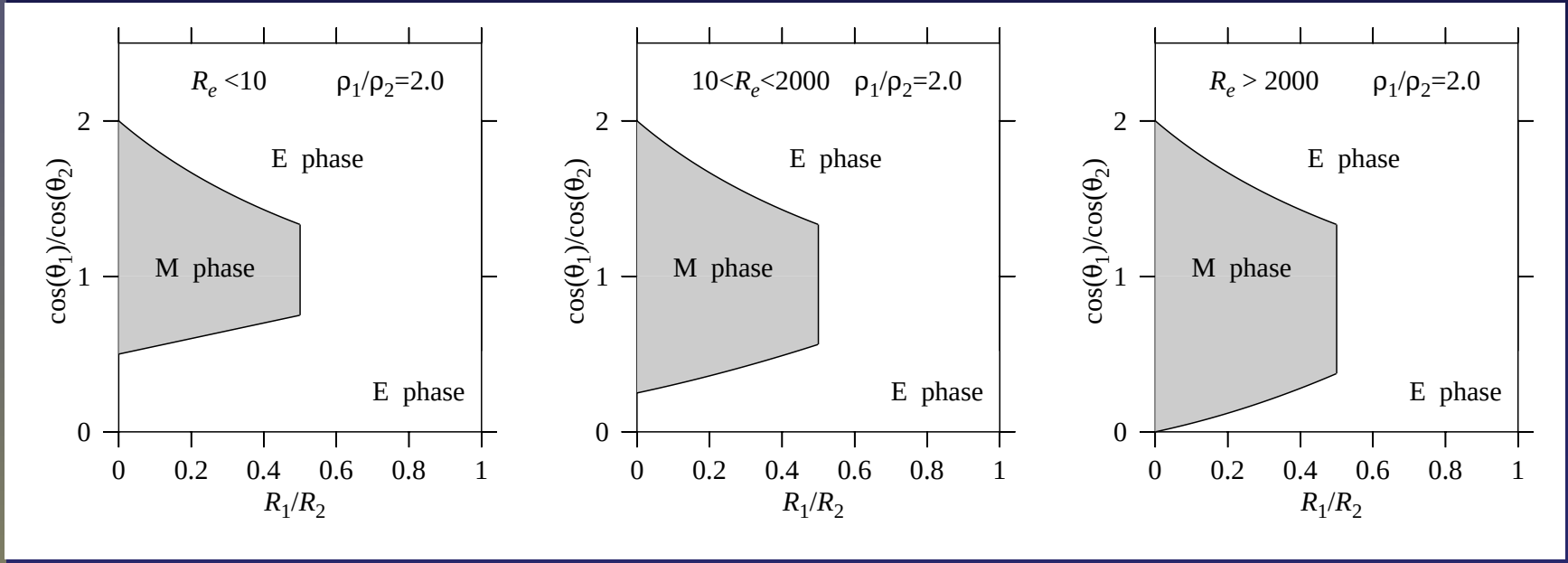
Sheared Phases



Gas-Solid Phases – Same Density



Gas-Solid Phases – Diff. Density



Outlook

- Cohesion may be well characterized using discrete tools
- Controlling mixing/segregation works for psuedo-static systems
- Simulations/experiments in gas-solid and sheared systems are necessary

Acknowledgments

- National Science Foundation
- Department of Energy – NETL/UCR
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